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Collection of Fly Ash with High Electrical Resistivity in a Pilot Plant Electrostatic Precipitator Preceded by the EPA/SoRI Precharger

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It is well known that dust with high electrical resistivity is difficult to collect in electrostatic precipitators (ESP). The difficulty is primarily due to poor particle charging. This poor particle charging is not because particles having high electrical resistivity are intrinsically difficult to charge, but because back corona (which results from deposition of material on the collection electrode) produces a bipolar ion field. When ions of both positive and negative polarity are present in the charging region, the competing effects of the two, plus low values of electric field, produce low electrical charge on particles.

EPA has contracted with Southern Research Institute (SoRI) to develop a novel ESP consisting of a precharger and of a downstream collector. The precharger has been built. The downstream collector is still being designed. The experiments described in this paper were designed to demonstrate the effectiveness of the precharger and to provide information needed to design the downstream collector. The data presented here are the first published data demonstrating the

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16. ABSTRACT The paper describes experiments designed to demonstrate the effectiveness of a precharger--part of a novel electrostatic precipitator (ESP)--and to provide information needed to design a required downstream collector. The paper presents the first published data demonstrating the effect of the precharger on particle collection in an ESP. Graded penetration curves indicate that rapping reentrainment may be a problem. The penetration of large particles is higher than expected and is probebly due to reentrainment. An optimized downstream collector should minimize the rapping reentrainment problem. The paper concludes that the precharger more than doubles the specific collector area of the ESP. Initial capital cost estimates indicate that the precharger will cost about a third to half the cost of one conventional electrical section. A conventional electrical section might increase the SCA of a small ESP, such as used for high sulfur coal, by as much as 33% and the SCA of a large ESP, such as used for low sulfur coal, by no more than 17%. Thus the cost effectiveness of the precharger appears to be excellent. Pilot and prototype scale field tests are planned to confirm the initial results.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Fly Ash	Stationary Sources	21B
Electrical Resistivity	Precharging	20C
Electrostatic Precipitation	EPA/SoRI Precharger	13H
Charging		14G

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effect of the EPA/SoRI precharger on particle collection in an ESP.

The EPA/SoRI Precharger

The EPA/SoRI precharger has been fully described by Pontius and Sparks[1] and Pontius, *et al.*[2] who presented data showing the effectiveness of the precharger in charging particles—but did not present data on particle collection in a device preceded by the precharger.

Experimental Apparatus

The experiments were conducted in a one-lane pilot plant ESP located in EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC. The ESP was operated with plate-to-plate spacing of 22.9 cm (9 in.). The discharge electrodes were selected to maximize the electric field for a given current density. Several different discharge electrode geometries were tried including: screen electrodes, 0.318 cm diameter wire, 2.54 cm apart; 0.635 diameter wires, 5.08 cm apart; and 0.635 cm diameter wires, 2.54 cm apart. Once the discharge electrode wires became dirty they all gave essentially the same voltage current (V-I) curves. A set of typical dirty wire/dirty plate V-I curves is shown in Figure 1.

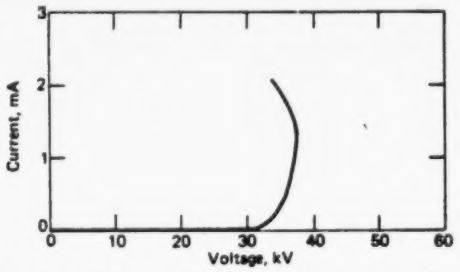

Figure 1. Typical dirty wire/dirty plate V-I curves for high resistivity case.

The precharger was installed in the inlet duct to the ESP. The precharger was a two-lane precharger with plate-to-plate spacing of about 13 cm (5 in.). Each lane had a single discharge electrode.

Sampling was conducted using sampling ports located after the precharger and before the ESP, and at the ESP outlet. Mass samples were collected using an out-of-stack filter. Impactor sampling was conducted using Meteorology Research, Inc. cascade impactors. The cascade impactors were calibrated by personnel of EPA/Industrial Environmental Research Laboratory's Particulate Technology Branch (PATB), using the procedure described by Calvert, *et al.*[3]

The dust used in these experiments was a fly ash which was injected into the ESP through two sand blast guns. The particle size distribution of the resuspended fly ash was approximately log-normal with a geometric mass mean physical diameter of about 8.5 μm and a geometric standard deviation of about 3. The resistivity of this fly ash is about 10^{12} ohm-cm at 150°C when no steam is injected and 10^{10} ohm-cm at 20°C. Steam injection at 150°C reduced the resistivity to about 5×10^{11} ohm-cm.

All data were reduced using TI-59 programmable calculator programs reported by Sparks.[4]

Results

The average graded penetration curve for the high resistivity fly ash (~10^{12} ohm-cm) for both precharger-off and precharger-on is shown in Figure 2. These graded penetration curves were used to calculate effective migration velocities, $w_e(d_i)$, for various particle diameters.

$$w_e(d_i) = \ln Pt(d_i)/(A/V) \quad (1)$$

where $Pt(d_i)$ is the penetration of particles with diameter d_i, and A/V is the specific collector area (SCA).

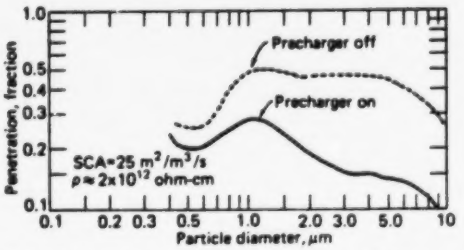

Figure 2. Graded penetration curves for high resistivity runs.

The effective migration velocities are plotted in Figure 3.

The graded penetration curves indicate that rapping reentrainment may be a problem. The penetration of large particles is higher than expected and is probably due to reentrainment. An optimized downstream collector should minimize the rapping reentrainment problem.

The graded penetration curve for the low resistivity case is shown in Figure 4.

Design to Meet NSPS

The effective migration velocity curves can be used to estimate the SCA required for a given penetration or a given emission such as required to meet New Source Performance Standards (NSPS). The overall penetration can be estimated from

$$Pt_0 = \sum_{i=1}^{\infty} \exp\left[f_i A/V w_e(d_i)\right] \quad (2)$$

where f_i is the fraction of the total mass at the inlet with diameter d_i, $w_e(d_i)$ is the effective migration velocity of particles with diameter d_i, and A/V is the SCA.

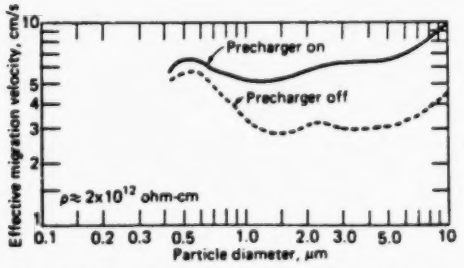

Figure 3. Effective migration velocity versus particle diameter for high resistivity runs.

Eq. (2) was solved for a typical fly ash size distribution, various values of SCA, and $w_e(d_i)$ taken from Figure 3. The particle size distribution was assumed to be log-normal with $d_g = 20$ μm and $\sigma_g = 4.5$. The results of these calculations are shown in Table 1. Based on these calculations it appears that an SCA of 70 $m^2/m^3/s$ (355 $ft^2/10^3$ acfm) may be adequate to meet the proposed NSPS of 13 ng/J (0.03 lb/10^6 Btu). This is less than half the SCA required for a conventional ESP.

Conclusions

Although the ESP was not the optimum downstream collector, particle collection by the precharger/ESP combination was excellent. With a specific collector area (SCA) of 29.2 $m^2/m^3/s$ (128 $ft^2/10^3$ acfm) the particulate emissions from the ESP without precharger were 2.5 times the particulate emissions from the precharger/ESP combination when collecting a dust with electrical resistivity greater than 10^{12} ohm-cm. The particulate emissions from the ESP alone were 15 times the particulate emissions from the combination when collecting a dust with electrical resistivity of about 10^{10} ohm-cm. The graded penetration (penetration versus particle diameter) curves show results consistent with those of the mass emission tests.

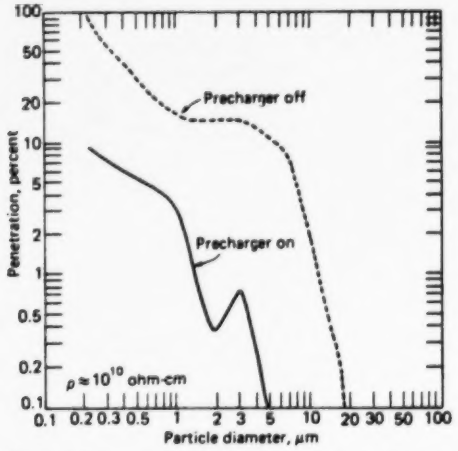

Figure 4. Graded penetration curves for low resistivity runs.

It appears that the precharger more than doubles the effective SCA of the ESP. Initial capital cost estimates indicate that the precharger will cost about a third to half the cost of one conventional electrical section. A conventional electrical section might increase the SCA of a small ESP, such as used for high sulfur coal, by as much as 33% and the SCA of a large ESP, such as used for low sulfur coal, by no more than 17%. Thus, the cost effectiveness of the precharger appears to be excellent.

Table I. Estimated overall penetration for various SCA in novel ESP collecting fly ash with high resistivity.

SCA			
$m^2/m^3/s$	$(ft^2/10^3$ acfm)	Pt_0	E%
25	(127)	0.087	91.30
40	(203)	0.031	96.9
50	(254)	0.016	98.4
60	(304)	0.0083	99.17
70	(355)	0.0044	99.56
75	(381)	0.0032	99.68
80	(406)	0.0023	99.77

The data were used to estimate the SCA needed to meet an emission standard of 13 ng/J (0.03 $lb/10^6$ Btu) when collecting fly ash with electrical resistivity of about 10^{12} ohm-cm. The estimated SCA is 70 $m^2/m^3/s$ (355 $ft^2/10^3$ acfm) which compares with an estimated SCA of at least 180 $m^2/m^3/s$ (930 $ft^2/10^3$ acfm) for a conventional ESP.

Pilot scale (~0.5 m^3/s) and prototype scale (~14 m^3/s) field tests plus more pilot plant tests are planned to confirm these initial results.

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